A Diagnosis of Maxillary Sinus Fracture with Cone-Beam CT: Case Report and Literature Review

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Abstract

The purpose of this article is to present the case of maxillofacial trauma patient with maxillary sinus fracture diagnosed with cone-beam computed tomography (CBCT) and to explore the applications of this technique in evaluating the maxillofacial region. A 23-year-old male patient attempted to our clinic who had an injury at midface with complaints of swelling, numbness. The patient was examined before in emergency center but any diagnosis was made about the maxillofacial trauma. The patient re-examined clinically and radiographically. A fracture on the frontal wall of maxillary sinus is determined with the aid of CBCT. The patient consulted with the department of maxillofacial surgery and it is decided that any surgical treatment was not necessary. The emerging technique CBCT would not be the primary choice of imaging maxillofacial trauma. Nevertheless, when advantages considered this imaging procedure could be the modality of choice according to the case.

Keywords

- maxillofacial imaging
- maxillary sinus fracture
- Cone-beam CT
- maxillofacial trauma

The causes of maxillofacial trauma vary among different countries and socio-economic levels, but include mainly traffic accidents, home accidents, falls, sports injuries, domestic violence, work-related injuries, and assault.[1–4] Maxillofacial trauma accounts for more than 60% of all traumatic injuries. Young men aged 16 to 30 years are exposed to trauma at more than twice the rate of young women in the same age group.[5] Maxillofacial injuries range from isolated fractures involving a small number of osseous structures to complex facial injuries extending over the entire facial skeleton. Until proven otherwise, all patients with severe facial injuries should be treated as though a neck injury has also been incurred.

Diagnosis and treatment of facial fractures requires a multidisciplinary approach[6] that involves both clinical examination and imaging, if necessary with multiplanar imaging procedures.[7] Diagnostic imaging plays a critical role in terms of obtaining information for initial diagnosis and treatment. Cone-beam computed tomographic (CBCT) technology has recently been improved to offer access to cross-sectional imaging that is faster and easier than hospital-based practices.[8]

CBCT was developed in the 1990s and was introduced for dentomaxillofacial imaging in 1998. The technique is suitable for imaging maxillofacial hard tissue as well as dental applications.[9] The following case reports on the case of a maxillary sinus fracture diagnosed using CBCT. To the best of our knowledge, no published study has reported on CBCT imaging of a maxillary sinus anterior wall fracture.

Applications of Cone-Beam CT in Maxillofacial Complex Fractures

Before the introduction of CT and magnetic resonance imaging (MRI) in the 1980s, plain radiography with two-dimensional (2D) images was the only imaging procedure available for assessing maxillofacial injuries.[5] Conventional CT has been used in clinical practice as a diagnostic tool in planning dental implants, evaluating the temporomandibular joint (TMJ) and

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identifying the relationship between an impacted third molar and the inferior mandibular canal.[10–13] The use of three-dimensional (3D) CT imaging technologies to visualize the maxillofacial region had become popular in both medical and dental practice. Although this usually requires consultation with a medical radiologist, these procedures offer several advantages over conventional imaging techniques.[14–16] CBCT may be considered the technology that has had the greatest impact on maxillofacial imaging over the past decade. The use of conventional CT is limited in dental practice due to high radiation doses, generation of image artifacts by metal-containing dental materials, costs, and accessibility. MRI may be considered in cases where detailed soft-tissue visualization is needed, including injuries of the TMJ, hemarthrosis, paranasal sinuses, and traumatic aneurysms.[17] However, MRI has limited capacity to depict bony details, requires hospital conditions, and entails higher costs. Recent studies suggest that 2D radiography (e.g., panoramic, periapical, occlusal, lateral radiograms) is adequate for initial examination, although tomographic imaging may be helpful when secondary signs and symptoms suggest potential fractures or displacements.[18]

CBCT image acquisition differs considerably from that of medical CT.[19,20] Image capturing of the maxillofacial region with a CBCT scanner involves a single rotation of the X-ray tube and detector around the patient's head. In routine maxillary implant planning, CT delivers a dose of more than 2.100 µSv, corresponding to 375 panoramic radiography dose, whereas a high-resolution CBCT image of the maxilla delivers only 18 µSv and with a reduced scan time.[7,19,21–23] An assessment of CBCT imaging suggests it offers superior capabilities in terms of multiplanar tissue evaluation, 3D views, lower radiation doses, less time, reduced costs and equipment requirements, and high image quality.[24–27] Some authors have also suggested that CBCT may be used effectively in head-and-neck imaging.[10,11] Besides these advantages CBCT has some important limitations and concerns. The most important disadvantage of this imaging technique is limited capability of soft-tissue visualization. Other important point is limited field of view (FOV) and limited scanned volume due to relatively small detector size. Also, image noise, low contrast range, and cone-beam–related artifacts are the other problems concerned with CBCT images.[28,29]

Recent innovations in CBCT scanners make it possible to adjust FOV based on the needs of the clinician, as follows: dentoalveolar, $<$ 8 cm FOV; maxillomandibular, 8 to 15 cm FOV; skeletal, 15 to 21 cm FOV; and head and neck, $>$ 21 cm FOV.[30] This translates into an ability to minimize the radiation exposure to the region of interest through a process of collimation, in line with the ALARA principle (i.e., "as low as reasonably achievable"). Thus, CBCT is more reliable than conventional CT in dental practice.

The high-resolution of CBCT, which can be attributed mainly to its smaller isotropic voxel size, represents an advantage; however, its inability to evaluate soft tissue and bone quality, including bone-mineral density, may be considered a disadvantage CBCT.[31]

Following scanning, device-specific software enables merging and visualization of CBCT datasets. Software programs allow clinicians to visualize and interact with data through four operative views: axial, cross-sectional, panoramic, and 3D reconstruction.[32] Different tools are available (e.g., measurement, simulation) to evaluate each individual anatomy in an ultimate overview.

The majority of maxillofacial traumatic injuries occur in the dentition alone (50%), compared with injuries to the maxillofacial skeleton alone (3.6%) or in association with soft-tissue injuries (10%).[18] Facial fractures are observed more often in the zygoma or mandible than in the maxilla.[33] Midfacial fractures include naso-orbitoethmoidal fractures, isolated maxillary fractures, and Le Fort-type fractures.[22] The latter, which may be subdivided into Le Fort I, II, and III fractures, occur as a result of localized direct or projectile trauma.[4,34–36] Facial edema, ecchymosis, epistaxis, nasal obstruction nose, orbital margin deformity, trismus, pain, and abnormal nerve sensitivity are often seen in maxillofacial trauma cases.[5] Facial swelling may conceal facial deformities; therefore, any signs of tenderness, crepitation, or irregularity in occlusion should be carefully evaluated.

Maxillofacial fractures may be broadly categorized as either dentoalveolar, mandibular, or midfacial fractures.

Dentoalveolar Fractures

Simple fractures of the alveolar process may involve the buccal or lingual cortical plates. These fractures are most prevalent in children aged 8 to 9 years and in the anterior segment of the maxilla.[33,37]

Dentoalveoler trauma most commonly presents as clinical crown fractures of adjacent teeth and can be adequately evaluated using periapical radiographs. Intraoral radiographs are often unable to reveal cortical plate fractures, and it may be difficult to differentiate a tooth fracture from an overlapping alveolar fracture.[33] When compared with periapical radiographs, CBCT has been found more successful in diagnosing root fractures.[38–40]

Mandibular Fractures

The mandible is the 10th most commonly injured bone in the body and, following the nasal bone, the second in the facial skeleton.[41] These fractures occur as a result of direct and indirect trauma to the head and neck. The most common fracture sites in the mandibular bone are the corpus (body), symphysis, condyle, angulus, ramus, coronoid process, and alveolar crest, respectively.[7] Initial assessment of a jaw fracture can be performed with plain radiographs such as occlusal films, panoramic views, posteroanterior projections, and submentovertex (SMV) skull views. However, nondisplaced fractures of the mandibular condyle can be very difficult to diagnose with conventional imaging techniques; therefore, it is important to supplement them with advanced imaging techniques such as CBCT.

Midfacial Skeleton Fractures

The midface comprises the nasal, maxillary, and zygomatic bones. The majority of cases of midfacial fracture are multifragmented or complex fractures that may involve several important structures, including the cranial base.[7] Midfacial fractures can be described as follows: (1) Le Fort fractures; (2) zygomaticomaxillary complex fractures; (3) nasal fractures; and (4) orbital fractures.

Le Fort Fractures

Maxillary fractures were classified by Rene Le Fort, who worked on cadavers with various types of facial trauma. Le Fort found certain patterns of fractures and divided midfacial fractures into three subgroups: Le Fort I, Le Fort II, and Le Fort III.

Le Fort I fractures separate the palate from the midface along a horizontal line that follows a route immediately above the roots of the maxillary teeth and palate. They occur as a result of direct trauma to the upper jaw region. The fracture lines extend from the pterygoid plates to the anterolateral margin of the nasal fossa, and the succession of fractures results in a floating palate.

Le Fort II fractures generate a pyramidal fracture line that extends from the dorsum of the nose to the lacrimal bone, medial orbital wall, orbital rim, and pterygoid plates and often involves the cranial base via the ethmoid bone.[7,17] These fractures result from a direct severe blow to the central facial region and are often accompanied with other injuries (orthopedic, neurologic, and hemorrhagical) due to the large amount of traumatic force.[42]

LeFort III fractures represent a craniofacial disjunction, with the fracture line passing through the nasofrontal suture, maxillofrontal suture, orbital wall, and zygomatic arch. LeFort III fractures are the most severe of the LeFort fractures, and patients with this type usually have multiple, complex fractures.

Zygomaticomaxillary Complex Fractures

The zygomatic arch plays an important role in the facial contour, and these fractures usually occur as the result of acute, direct trauma to the side of the face. Malpositioning of the zygomatic arch can also affect the normal projection of the coronoid process of the mandible and can cause difficulties in mouth opening.[7,43] The SMV view, which is traditionally used as the first step in the diagnosis of zygomatic arch fractures, as well as Towne view may show both zygomatic arches more easily, especially in the case of patients who cannot tolerate head extension.

Nasal Fractures

Conventional radiography using a lateral image is the gold standard in the radiological display of nasal bone fractures.[44] Bremke et al noted that some authors doubt the value of radiography in diagnosis of a nasal bone fracture and suggest CBCT as a useful alternative because of its high resolution, ease of use, and low radiation dose in comparison to conventional CT scans.

Orbital Fractures

Trauma to the central midface frequently results in fractures of the nasoethmoid orbital skeleton, a complex area that consists of a union of bones from the nose, orbits, maxilla, and cranium. Orbital fractures may be the most difficult and challenging of all facial fractures to diagnose and treat.

2D imaging does not appear to sufficiently assess the reduction of complex fractures. Stuck et al reported that intraoperative CT scanning is expensive and rarely available. CBCT provides some technical and practical advantages; for example, the FOV allows imaging and 3D reconstruction of the entire facial skeleton to ensure symmetric fracture reduction, and the resolution of the image is sufficient for evaluating even delicate bony structures.[45]

Maxillofacial trauma causes severe clinical problems because of the anatomical characteristics of the region, and 34% of the cases are accompanied by major trauma.[3,18] 3D imaging is essential for locating anatomic and pathologic components and can provide views of both hard and soft tissue, whereas 2D projections are of limited use because of superimposition, magnification, distortion, and misrepresentation of structures. Many studies have examined the geometrical accuracy of CBCT and have concluded that the technology makes it possible to inspect the 3D bony topography and adjacent vital structures with high accuracy.[24,46,47] The main challenge in CBCT imaging and diagnosis is the lack of familiarity with the concept of multiplanar imaging experienced by most dental professionals. 2D imaging modalities have been taught for several decades in dental schools and other training courses, whereas sectional imaging is offered only by some contemporary imaging modalities, such as medical CT, MRI, ultrasound, and CBCT.[48] This new exciting technology should not be considered as a replacement for panoramic or other conventional projections, but rather as a complimentary modality of imaging in clinical dental practice.

Case Report

A 23-year-old male patient sustained a traumatic injury to the midfacial region when he collided with a goal post during a football match. The patient reported to hospital emergency services immediately after the accident with a complaint of nausea. A head CT (►**Fig. 1**) and Waters projection (see ►**Fig. 2**) were taken, and it was explained to the patient that no treatment was necessary.

The following day, the patient presented at the Department of Maxillofacial Radiology with the complaints of swelling, numbness, and loss of sensation in the right maxillary premolar–molar gingival area and the right half of his upper lip. An extraoral clinical examination showed facial edema, pain and irregularity in palpation of the adjacent orbital margin (►**Fig. 2**), and hypoesthesia of the right infraorbital sensory area. No ecchymosis or hemorrhage was observed.

Intraoral examination found no hematoma, mucosal laceration, or impairment of the maxillary or mandibular arches, and there was no pain on inspection, percussion, or palpation. A radiographic examination was performed that included panoramic radiography (►**Fig. 3**) and CBCT images of the maxilla taken with a 5 × 5 FOV (Vatech Pax Uni 3D [Vatech Co. Ltd., Seoul, Korea; April 4, 1992] Ez3D2009 Pc software program). The CBCT revealed a nonfragmented fracture line in the anterior wall of the maxillary sinus, which was evaluated from various perspectives (►**Fig. 4**).

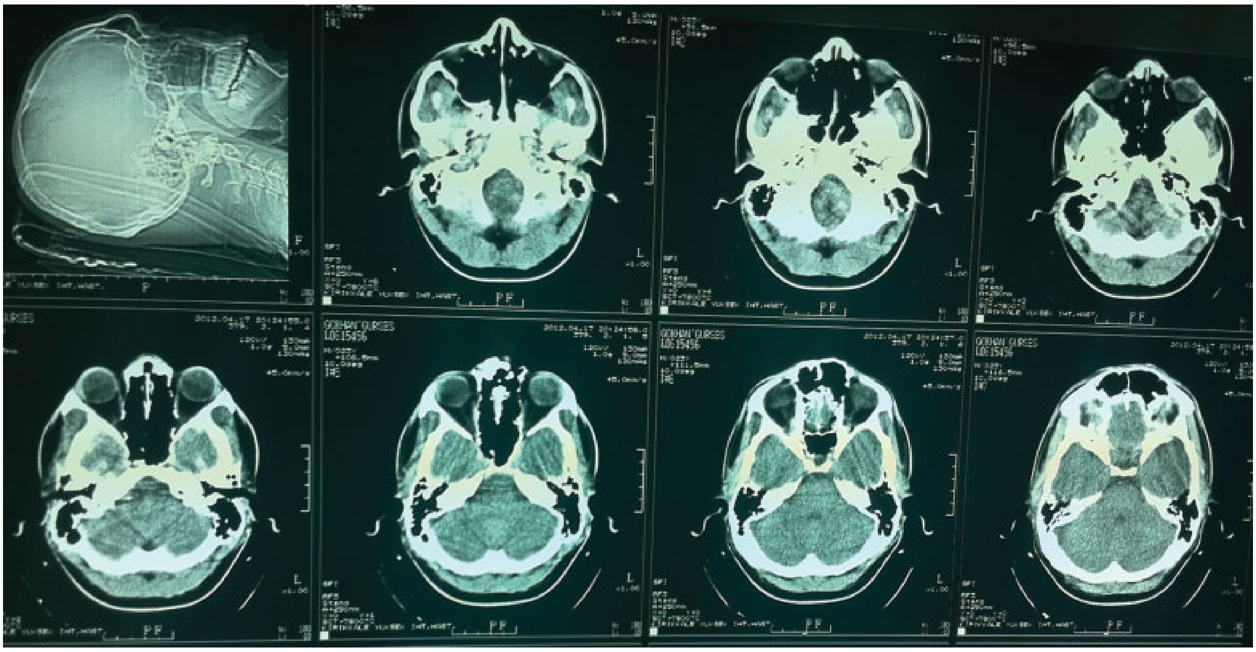

Figure 1 The head computed tomography images of the patient.

Following consultation with the oral surgery department, it was determined that no surgical treatment was necessary, and the patient was informed about the importance of follow-up. In a subsequent visit 2 days after the initial evaluation, an ecchymosis was found to have developed in the right infraorbital area. After 2 weeks, both the hypoesthesia and ecchymosis had subsided, but an irregularity in the adjacent orbital rim could still be observed. After 2 months, hypoesthesia regressed up to involved commissurae. In addition, any ecchymosis or hemorrhage was observed.

Discussion

Facial fractures may occur in isolation or accompanied by tissue injuries. Massive swelling may conceal deformities resulting from the fracture; however, without adequate, appropriate treatment, serious functional, and esthetical problems can emerge.[49,50]

Boeddinghaus and Whyte noted that while standard 2D radiographs may help in preliminary examination of maxillofacial trauma, diagnosis of an occult fracture may require tomographic imaging techniques, such as CBCT, that can provide excellent imaging of bony structures.[22] In line with this assertion, the occult fracture diagnosed by CBCT in the present study could not be distinguished by either panoramic radiography or Waters radiography. 2D Waters and Townes views have outdated their actuality with recent improvements in imaging technologies. CBCT seems to be a good complementary for panoramic radiography in trauma cases.

Figure 2 Waters projection and facial appearance of the patient. Extraoral clinical examination showed facial edema; no ecchymosis or hemorrhage was observed.

Figure 3 Panoramic radiograph of the patient.

Mihalik et al reported maxillofacial and dental injuries to be common occurrences in football and noted that diagnostic imaging plays a crucial role in the management of maxillofacial trauma, which may involve severe complications due to the anatomical aspects and intense vascularity of the region.[51] Furthermore, Scarfe emphasized the directory role of novel digital and tomographic techniques in maxillofacial trauma cases.[18] In the present case, CBCT was used to confirm a suspected facial fracture that occurred in a football game.

Shintaku et al noted that while plane radiography requires less ionizing radiation than CT and CBCT, it is capable of representing only limited data. When further information is needed, as in the case reported here, CBCT would be the appropriate choice in diagnosis, treatment planning, and postoperative examination.[7] Using CBCT, it was decided that the present case could be managed with careful follow-up, but that surgical treatment was not required. On the contrary, it should be considered that CBCT should not be used as a single imaging modality in polytrauma patients.

In a case report of a fracture in the posterior wall of the maxillary sinus, Simonds et al reported 3D volumetric imaging to offer sensitivity and adequate density in diagnosing maxillofacial fractures concealed by soft-tissue edema.[49] In our case, the fracture which diagnosed with CBCT was nonfragmented and there was a small amount of swelling in the trauma area.

A study by Schulze comparing diagnostic applications of CT, CBCT, and MRI in the dentomaxillofacial region reported CBCT to offer geometrical accuracy,[9] and Hassan and Jacobs reported that in comparison with 2D technologies, 3D technologies provide superior accuracy in imaging anatomical and pathological formations in the dentomaxillofacial region.[52] Although MRI may be considered an alternative to CT in cases involving the paranasal sinuses and soft tissue, MRI is unable to provide sufficient hard-tissue details, and it is not cost-effective. Furthermore, whereas a hospital setting and large areas are required to accommodate both MRI and CT devices, CBCT is a fast and simple procedure that can be performed routinely in the dentomaxillofacial department of our faculty. However, CBCT imaging is not appropriate in polytrauma cases with multiple fractures, walking or mental disabilities which the patient needs to be in supine position.

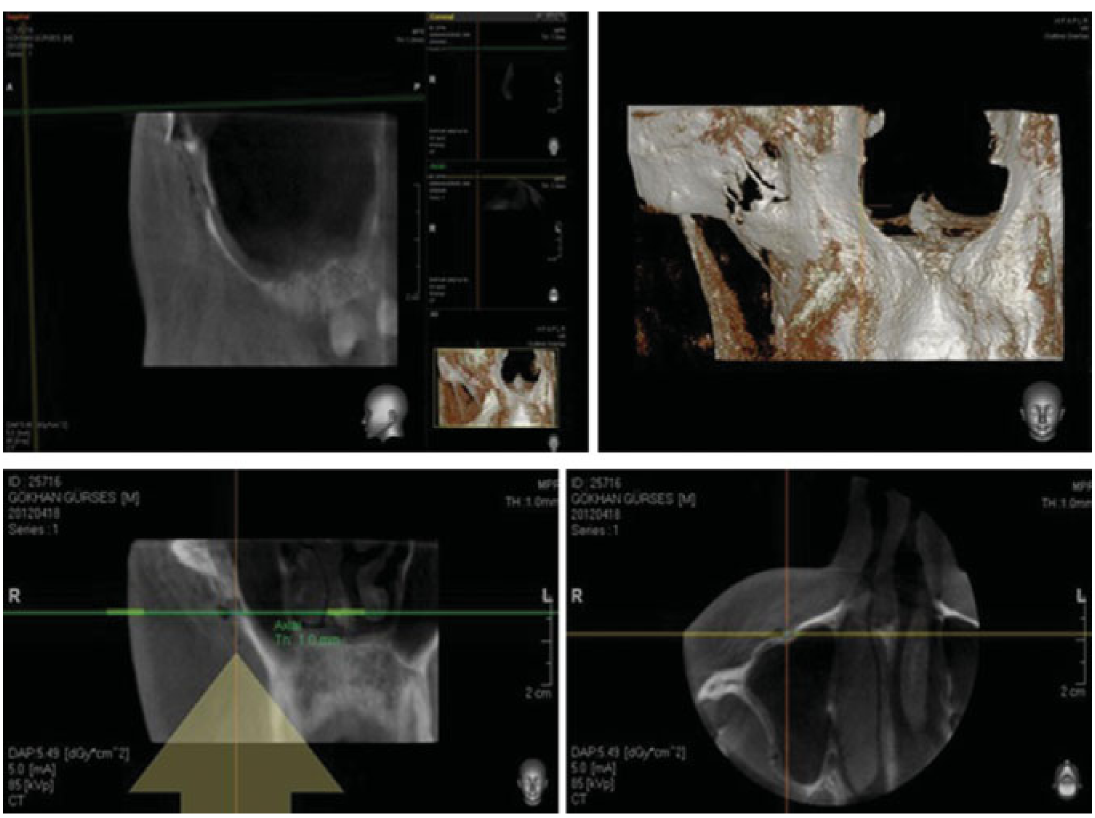

Figure 4 Cone-beam computed tomography images of the patient showing a nonfragmented fracture line in the anterior wall of the maxillary sinus.

Heiland et al stated that the use of CBCT for preoperative, intraoperative, and postoperative imaging can decrease radiation doses in cases of zygomaticomaxillary complex fractures, while CT crucial in cases where there are neurological symptoms or severe injuries.[8,53] In our case, CBCT was used to diagnosis a maxillary sinus fracture, and follow-up including clinical examination only, with no further imaging.

Schulze et al reported CBCT to be a reasonably good alternative to CT for facial skeleton examination, offering high imaging accuracy with reduced radiation exposure.[12] In the case presented here, a CT examination of the patient performed before the application to our clinic had failed to identify a maxillary sinus fracture.

Ahmad et al and Morimoto et al stressed that while CBCT may be a crucial diagnostic tool in maxillofacial surgery, its capabilities and limitations need to be well understood; for instance, CBCT may be used successfully for topographical bone imaging, but it may not be sufficient for soft-tissue imaging or evaluation of bone height.[8,31] Also, CBCT has a limited FOV. Our system is capable of providing two different choices of FOV. Nevertheless, it must be kept in mind that a larger imaging volume proceeds poorer object resolution and insufficient object detail.

Shahbazian and Jacobs evaluated maxillary sinusitis cases of odontogenic provenance using 2D and 3D imaging procedures and found CBCT to offer more advantages thanks to its high-contrast resolution and lack of superpositions.[13] Maillet et al investigated the relation between the maxillary sinus and maxillary posterior teeth roots using CBCT and declared that CBCT imaging of this region can be effective in maxillary sinusitis management.[54] In our case, we evaluated the mentioned sinus antrum and the anterior wall with cross-sectional and 3D images found any findings of sinusitis.

Conclusion

A review of the literature highlights the increasing use of CBCT in the evaluation of facial structures following maxillofacial trauma. In addition to maxillofacial trauma cases, CBCT appears to be suitable for use in TMJ imaging, implant planning, pre- and postoperative evaluation, and imaging of dentomaxillofacial pathologies in clinical practice.

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